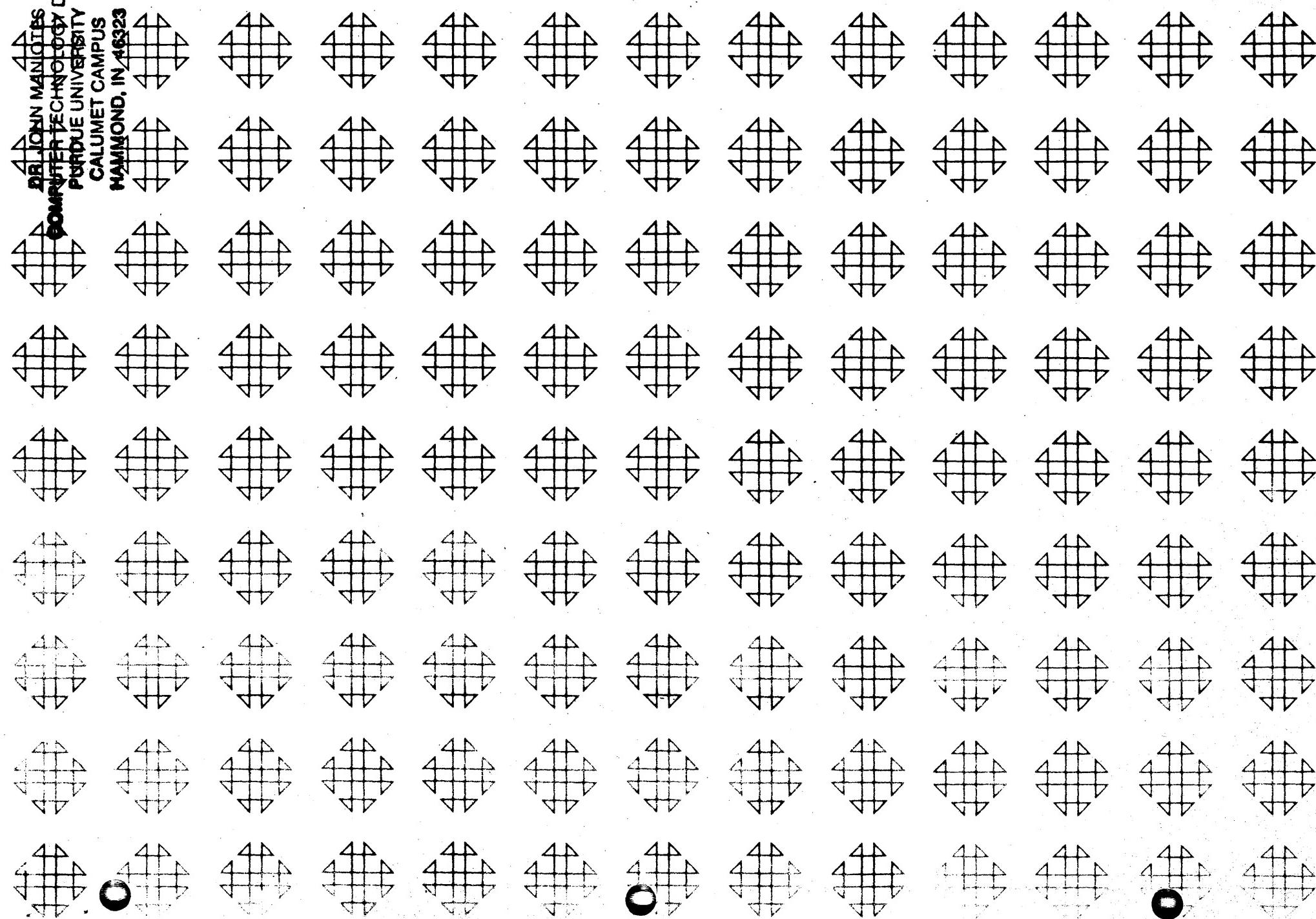


JOHN MANZES
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HAMMOND, IN 46323

1620 GENERAL PROGRAM LIBRARY

Eigenvalues of Real Symmetric Matrices on the 5.0.003
1620 Data Processing System



1620
Correction

5.0.003
Oct. 7, 1965

The authors new address is as follows:

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Oakland, California
94804

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ERRATA

**EIGENVALUES OF REAL SYMMETRIC MATRICES
ON THE
1620 DATA PROCESSING SYSTEM
(CARD)**

Page 5 - bottom - add

This procedure yields the TRANSPOSE of the Eigenvectors. The matrix identification is then reversed on printing to yield proper subscripting.

Page 8 - OVERFLOW CHECK SWITCH

Should be set to PROGRAM.

Phase 3 basic and Phase 3 Auto Divide -- "TYPEV" block should read:

02758	25	0397102426	To Type + 6, Out J-2
02770	25	0397302427	To Type + 8, Out J
02782	25	0396502428	To Type + 12, Out I-1
02794	25	0396702429	To Type + 14, Out I

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6/14/61

FILE NO.

ABSTRACT

05.0.003 IBM 1620-EIGENVALUES OF REAL SYMMETRIC MATRICES ON THE 1620 DATA
PROCESSING SYSTEM ***CARD***
AVAILABLE 1ST QUARTER 1962

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HONOLULU 13, HAWAII

DIRECT INQUIRIES TO AUTHOR

WILL SOLVE FOR THE EIGENVALUES AND ASSOCIATED EIGENVECTORS
OF A REAL, SYMMETRIC MATRIX TO ORDER 50. FLOATING POINT
ARITHMETIC IS USED FOR ALL CALCULATIONS IN PHASE 2 AND 3.
NO OTHER SUBROUTINES ARE USED IN ANY OF THE THREE PHASES.
20,000 POSITIONS OF CORE STORAGE ARE UTILIZED BASIC 1620
CARD SYSTEM WITH DIRECT DIVISION AND INDIRECT ADDRESSING.

THIS PROGRAM AND ITS DOCUMENTATION WERE WRITTEN BY AN
IBM EMPLOYEE. IT WAS DEVELOPED FOR A SPECIFIC PURPOSE AND
SUBMITTED FOR GENERAL DISTRIBUTION TO INTERESTED PARTIES
IN HOPE THAT IT MIGHT PROVE HELPFUL TO OTHER MEMBERS OF
THE DATA PROCESSING COMMUNITY. THE PROGRAM AND ITS
DOCUMENTATION ARE ESSENTIALLY IN THE AUTHORS ORIGINAL
FORM. IBM SERVES AS THE DISTRIBUTION AGENCY IN
SUPPLYING THIS PROGRAM. QUESTIONS CONCERNING THE USE OF
THE PROGRAM SHOULD BE DIRECTED TO THE AUTHORS ATTENTION.

PROBLEM DEFINITION

The physical reasons for wishing to solve the eigenvalue problem come from a wide variety of fields, including vibration analysis, factor analysis and systems in dynamic equilibrium. Probably the most basic reason comes from the frequent need to solve a system of n linear differential equations in n unknowns:

$$\begin{aligned}x_1' &= a_{11}x_1 + \dots + a_{1n}x_n \\x_2' &= a_{21}x_1 + \dots + a_{2n}x_n \\&\dots \\x_n' &= a_{n1}x_1 + \dots + a_{nn}x_n\end{aligned}$$

(1)
If the column vector $(x_1 \dots x_n)^T$ is denoted by x , then this can be written as a single matrix equation

$$x' = Ax$$

where A is the $n \times n$ coefficient matrix.

A solution to this equation in the form $x = Ve^{\lambda t}$ is sought, where V is a column vector. This leads to the equation $Ve^{\lambda t} = Ae^{\lambda t}$ or $(A - \lambda I)Ve^{\lambda t} = 0$. Thus an eigenvalue, together with a corresponding eigenvector V , yields a solution $x = Ve^{\lambda t}$ of the matrix differential equation.

For an $N \times N$ square, symmetrical matrix, A , the problem to be solved is to find a number λ and a vector V such that $AV = \lambda V$. Each λ is referred to as an eigenvalue, characteristic root or latent root of the matrix A , and each related N -dimensional vector, V , is called an eigenvector or characteristic vector corresponding to the eigenvalue. The eigenvectors are mutually orthogonal, i.e., the inner or scalar product of any two resulting eigenvectors equals zero:

$$(V_i, V_j) = 0.$$

It can be shown that a solution exists if and only if

$\text{DET } |A - \lambda I| = 0$, where I is an N^{th} order unit matrix. This relationship results in an N^{th} degree polynomial which has, in general, N real eigenvalues or roots.

PROBLEM DEFINITION CONT.

The Jacobi Method

(1)

C. G. J. Jacobi has shown a method of reducing a real symmetric matrix A to diagonal form by a series of plane rotations. He proved that the diagonal entries of this reduced matrix are approximately the associated eigenvalues of A. Further, the off-diagonal elements can be made smaller than any pre-assigned value, Δ .

A plane rotation is an orthogonal, unitary matrix of the form

$$U_{ij} = \begin{bmatrix} 1 & & & \\ 1 & & & \\ 1 & & & \\ \vdots & & & \\ \cos \theta_{ij} & -\sin \theta_{ij} & & \\ \sin \theta_{ij} & \cos \theta_{ij} & & \\ & & & \\ 1 & & & \end{bmatrix}$$

Where θ is a function of a_{ii} , a_{jj} , a_{ij} of the original matrix A. Note that $U_{ij}^{-1} = U_{ij}^T$. If θ is chosen such that $\theta = 1/2 \tan^{-1} (2 a_{ij} / (a_{ii} - a_{jj}))$ then the element a_{ij} reduces to zero upon application of the similarity transformation $U_{ij}^T A U_{ij}$ and is said to be annihilated. Repeated operations of the form $U_{ij}^T \cdots U_{ij} A U_{ij}^T \cdots U_{ij}^T$ to the matrix A would eventually lead to a matrix consisting of the approximate eigenvalues along the principal diagonal and the off-diagonal elements less than any preassigned value, Δ , provided k is made large enough.

Jacobi annihilated the largest off-diagonal elements by the method shown above. The eigenvectors are then found by the matrix product

$U_{ij}^T \cdots U_{ij} I$ where k is the number of rotations required to form the eigenvalues, above.

1620 PROGRAM METHOD

The classical Jacobi method requires the evaluation of arctangent and square root functions. The method also necessitated a complete search of the matrix to determine the largest off-diagonal element which was then rotated. In the interest of speed and precision, the following method is employed in the 1620 program.

The rotation angle, θ , is approximated by:

$$\tan \theta/2 = r ; \quad r = a_{ij} / 2 (a_{ii} - a_{jj}),$$

if the absolute value of r is less than $\tan 22.5^\circ$.

If r is greater than or equal to $\tan 22.5^\circ$, then 45° is used for θ .

If r is less than or equal to $-\tan 22.5^\circ$, then -45° is used for θ .

The values of $\sin \theta$ and $\cos \theta$ which are needed for the rotation are then:

$$\sin \theta = \frac{2r}{1+r^2} \quad \cos \theta = \frac{1-r^2}{1+r^2}$$

which involve only simple arithmetic operations.

The selection of the elements to be rotated is:

- 1) During phase 1 a value for Δ , the precision required, is entered. Later, all off-diagonal elements will be rotated until they are less than Δ . An initial search argument, E, is generated in phase 1 also.
- 2) During phase 2 all off-diagonal elements greater than E are rotated until all a_{ij} ($i \neq j$) are less than E, whereupon E is replaced by $E/10$ and so on until E is less than Δ at which time phase 2 terminates.
- 3) After each rotation, a sense switch is interrogated to determine if the operator desires the rotation angle to be punched out for later use in phase 3.

1620 PROGRAM METHOD CONT.

Phase 2 Calculations:

(2) Since only the i^{th} and j^{th} rows and columns are affected by any one transformation, the matrix multiplications are replaced by the equivalent calculations and substitutions:

- 1) $a'_{ij} = a_{ij} (c^2 - s^2) + s c (a_{jj} - a_{ii})$
 - 2) $a'_{ii} = a_{ii} c^2 + a_{jj} s^2 + 2 a_{jj} s c$
 - 3) $a'_{jj} = a_{ii} s^2 + a_{jj} c^2 - 2 a_{ij} s c$
 - 4) $a'_{ik} = a_{ik} c + a_{jk} s$
 - 5) $a'_{ik} = a_{ik} c - a_{jk} s$

$k = 1, 2, 3, \dots, N; \text{ but } \neq i \text{ or } j$

where $s = \sin \theta$ and $c = \cos \theta$ and the primed elements replace the unprimed elements of the A Matrix.

Phase 3 Calculations:

Similarly, only the i^{th} and j^{th} rows of the matrix used to form the eigenvectors are affected by a particular rotation. The formulas used are:

- $$2) \quad V_{ki} = V_{ki} c_i - V_{ki} s_i \quad k = 1, 2, 3, \dots, N$$

INPUT - OUTPUT AND DATA PREPARATION

With the exception of the matrix size, N and the matrix coordinates I and J, all data is entered in standard 10-digit normalized floating point form.

First Card (columns 1 - 13)

N N △△△△△△△△△△△△△

N **N** is the matrix size in fixed point and is right justified. **N** must lie between 2 and 51.

$\Delta \Delta \Delta \Delta \Delta \Delta$ is the minimum search argument, delta for the desired precision. For instance, if it was desired that all off-diagonal elements be reduced to a value of less than .00000001, delta might be chosen as 4210000000 . See Procedural Options, page 16.

Succeeding Cards (columns 1 - 15)

I I J J A A A A A A A A A A \neq for each element on or above the principal diagonal.

I I is the row designation and must be less than or equal to J J
 J J is the column identification and must not be greater than N
 A A A A A A A A A is the matrix element in normalized floating point format.
 (-) A flag is punched over the low order A position for negative values.

Note that flags are not required for field definition. A recommended sequence for punching is by row, i.e., a_{11} , a_{12} , $a_{13} \dots a_{20}$, $a_{23} \dots$ etc.

Last Card(column 1)

* An additional record mark must follow the last record.
If errors are made in the punching of the matrix elements, they need not be corrected before operating the program. The operator will be given the opportunity of entering corrected record(s) from the console during phase 1. (See "ANY CHANGES," page 9.)

Output Records

Output cards and typewriter records are automatically prepared. (See sample problem.)

PROGRAM OPERATION - GENERAL

MACHINE REQUIREMENTS

- Program "A" Basic 1620 equipped with 1622 card read-punch.
Program "B" Basic card 1620 with direct division and indirect addressing features. Program B requires 6% less time than Program A for any given problem.

Other features, such as extra memory and additional instructions, have no effect on program operation.

A paper tape version of Program "A" is currently available from the 1620 program library.

I/O Check Switch----- STOP
OVERFLOW Check Switch---- STOP
PARITY Check Switch----- STOP

	<u>ON</u>	<u>OFF</u>
Sense Switch 1	Data on Cards	Data entered via typewriter
Sense Switch 2	Punch rotation angles	Do not punch rotation angles
Sense Switch 3	Data will type out to verify	Data will not type out
Sense Switch 4	Error entered from typewriter	Normal

When a typing error occurs:

- 1) Place sense switch 4 ON
- 2) Depress RELEASE, START
- 3) Place sense switch 4 OFF
- 4) Re-enter record correctly from typewriter.

Clear memory. (31 00003 00002)
Prepare card punch and typewriter forms. All program halts not accompanied by error typeouts or error indicators are normal. They are included to allow program or data preparation.

All three phases are loaded by standard SPS methods:

Depress Load Key, then START

The transition between phases, however, is done automatically.

PHASE 1

- 1) Load program and data cards into 1622 read hopper:
 - A. Phase 1 program
 - B. Control Record card
 - C. Data cards
 - D. Trailer card (record mark in column 1)
 - E. Phase 2 program
 - F. Phase 3 program
- 2) Depress LOAD
- 3) When machine halts, depress START
- 4) Follow instructions typed out on the console typewriter.

PHASE 1 CONT.

- 5) Typeouts will occur with the following messages and their indications:

LABEL TYPED	NORMAL	ERROR	CORRECTION POSSIBLE
CONTROL RECORD ERROR		X	Re-enter correct control record via typewriter
N=XX	X		
DELTA=xxxxxxxxxx	X		
MATRIX TOO LARGE		X	Re-enter correct control record
MATRIX TOO SMALL		X	Re-enter correct control record
DATA ERR OR ADDITION	X	X	Enter correct record: IIJAAAAAAAAAA ^{1,1} by typewriter, depress RELEASE and then START record too long record too short I greater than J J greater than N record mark missing
IJ DUPLICATED	X	X	If in error, correct by 'ANY CHANGES', below
SINGULARITY POSSIBLE	X	X	None, (AII less than .000001)
MATRIX LOADED	X		OK if last record is in
ANY CHANGES	X	X	Type YES ⁴ or NO ⁴ . If YES, enter any additions or corrections as in 'DATA ERR', above
COUNT WRONG		X	One or more elements are missing, enter as in 'DATA ERR', above

- 6) The program will load into storage exactly $N(N+1)/2$ records. Should the data deck contain more than this number, the last record entered for any I and J will dominate, i.e., will destroy the earlier record.
- 7) The field address of any diagonal element is given by:

Address= 07248 + 10 I for any (I, I).

The field address of any other element is given by:

Address= 07758 + J(J-3)*5 + 10 I for any A(I, J). (I#J)

- 8) Program execution time is $.3(N^2/2)$ seconds or slightly less than full read speed.

It is important that no changes to 1620 storage addresses above 07000 take place between phases 1 and 2. Phase 2 assumes the existence of the data matrix and certain other information left in storage by phase 1.

PHASE 1 CONT.

- 9) Phase 2 will be automatically loaded when Phase 1 terminates.

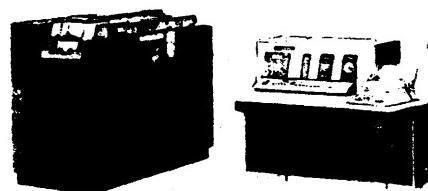
PHASE 2

- 1) Sense switch 2 on if the eigenvectors are desired.
- 2) Depress START.
- 3) Program execution time is about $.0052 N^3$ minutes. If the vectors are desired, punch time (3.4 milliseconds per rotation) must be added. The number of rotations performed is generally bounded by $1.3 N^2$ and $2 N^2$, depending on the size and conditioning of the matrix.
- 4) If sense switch 2 is on, i.e., the eigenvectors are desired, phase 3 automatically loads into memory, if sense switch 2 is off, the program terminates and the card reader is unloaded by the program.

PHASE 3

- 1) If the eigenvectors are desired, depress Reader START then START at the completion of phase 2. Follow instructions typed out on the console typewriter. Insure that all phase 2 output data cards (including the last one) follow phase 3.
- 2) A maximum of 32 eigenvectors will be typed out on the first pass. If N is greater than 32, reload the data cards now in the reader output hopper and hit START for the remaining N-32 vectors.
- 3) Average execution time = $.004N^3$ minutes.
- 4) Since phase 3 is independent of the other two phases, it may be run at any later time at the user's convenience. To operate phase 3 alone, perform the following operations:
 - (1) Clear memory (31 00003 00002)
 - (2) Load phase 3 program in Reader hopper.
 - (3) Depress LOAD key.
 - (4) When phase 3 loads, depress START.

PHASE 1 - MATRIX LOAD



N = Matrix Size

-11-

PHASE 1

Trailer Card

Matrix Data

Control Record

Matrix Loader
Phase 1

00402, Start
Clear Data
Area
Initialize

MATRIX LOAD

Tape
Read - N, D
RNCD or
RNTP

Verify Bad Error
Control Record Message
OK Last Record
Read: Read Z

I, J, AIJ
RNCD or RNTP

Gut
Error Invalid Test
Message Valid

Store AIJ
Return
Count +1

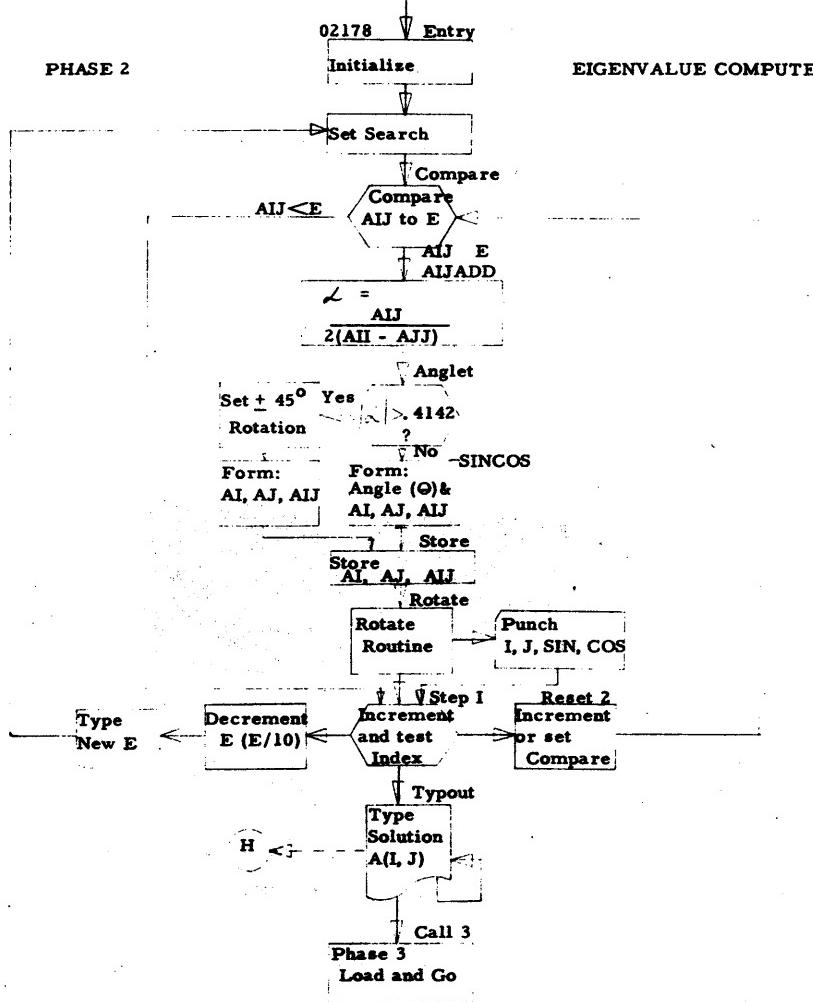
No End Ask
Interrogate
operator-End?
End
Tstend
Count No Count =
Short Error N(N+1)/2?
Message Yes
Exit
Instruc-
tions

Halt

Phase 2 Load
and Go

-11.1-

PHASE 2



-12.1)-

PHASE 3

02178 Entry

Set Pass 1

Clear

Set I Matrix

32 x 32 or

18 x 18

Readn

Read N

Read

I, J, SIN, COS

Type V Type VIJ

File Yes V1→VN V1→V32 or

End No V33→VN

Comput

Form Address:

V1I, V1J, VNI

EIGENVECTOR COMPUTE

Set Pass 2

No end

test end

H

θ = 45°

HRDWAY

VKI=VKI·C + VKJ·S

VKJ=VKJ·C - VKI·S

VKJADD + 24

VKI or J= $\sqrt{2}$ (VKI+VKJ)VKJ or I= $\pm \frac{1}{\sqrt{2}}$ (VKJ-VKI)

Store

VKI, VKJ

End

Yes VKI=VNI No K=K+1

Stop Addresses

-13.1-

PRECISION AND TIMING

For test purposes, two types of matrices are considered. A well behaved matrix C, and the notoriously ill-conditioned Hilbert matrix, H defined as:

$$C(I, J) = 2 D(I, J) - D(I, J + 1) - D(I, J - 1)$$

where D is the usual Kronecker delta function, i.e. $D(I, I) = 0$; $D(I, J) = 1$

for $I \neq J$ and $H(I, J) = 1 / (I + J - 1)$.

The eigenvalues of C are given by $\lambda_i = 4 \sin^2 ((\pi * i) / (2n + 2))$

$$i = 1, 2, \dots, n.$$

A moderately conditioned matrix, X, was also tried.

Test results were:

Matrix Size	C, H or X	Time	Precision (No. of Correct Digits)
5	H	65	seconds 4
6	X	90	seconds 7
7	H	2	minutes 1
10	C	5-1/4	minutes 7
10	H	8	minutes 0
20	C	29	minutes 4
20	C	32	minutes 5
20	C	38	minutes 6

Since the floating point routines do not round after arithmetic operations, a general deterioration of precision is to be expected in the results of this program.

Program "B" requires 6% less time than program "A".

The reader will notice minor discrepancies between the results of program A and B. These are due to the computational differences of the direct divide and programmed divide methods. The results from program B have proved, in general, to be more accurate.

PROCEDURAL OPTIONS

The procedure of reducing all off-diagonal elements to a machine zero (delta) raises a problem in the selection of this input variable. If delta is chosen either too large or too small, precision will be lost. The effects of incorrectly choosing delta are:

- 1) Delta too large -
 - a) fast processing speeds
 - b) moderate to large error in Phase 2
 - c) moderate to large error in Phase 3
 - d) may necessitate a re-run to obtain the precision required.
- 2) Delta too small -
 - a) slow processing speeds, particularly in Phase 3
 - b) small to moderate truncation errors in Phase 2
 - c) moderate to large errors in Phase 3
 - d) very large errors and floating point overflows if less than about 10^{-20} .

The author has found empirically that the relation

$$\text{DELTA} = \text{MAXIMUM AIJ } (I \neq J) * 10^{-9}$$

is very close to an optimum value in terms of precision and speed, with precision very heavily weighted. Deviations from this value by a factor of 10 affect the results to a small degree. Increasing delta by a factor of 10 results in a small time reduction, whereas decreasing delta by a factor of 10 results in a very small increase in precision.

REFERENCES

- 1) P. White, Eigenvalue and Eigenvector Computations of a Matrix, Journal of the Society for Industrial and Applied Mathematics 4 (1958). Pages 393-437.
- 2) Howell, Hall, Eigenvalues of Real Symmetric Matrices by the Jacobi Method. IBM 650 program library file No. 5.1.006.
- 3) Corbato, IBM SHARE, 704 library program MI HDII - May, 1958.

THIS IS A COMPLETE RECORD OF CONSOLE OPERATIONS FOR THE 1620 EIGENVALUE PROGRAM.
TEST MATRIX 3 X 3 - SWITCHES 1, 2 AND 3 ON. BASIC CARD 1620.

310000300002
SS1 ON-DATA ON CARDS, OFF-DATA ENTRY VIA TYP.
SS2 ON-PUNCH ROTATION ANGLES, OFF-NO PUNCH.
SS3 ON-DATA TYPED OUT TO VERIFY, OFF-NO TYPE.
SS4 ON-ERROR ENTERED FROM TYP., OFF-NORMAL.
CLEAR CARD PUNCH AND READY FORMS.
PLEASE LOAD DATA AND HIT START

N= 03 , DELTA = 4110000000
A(01,01) = 5120000000
A(01,02) = 5110000000
A(01,03) = 0000000000
A(02,02) = 5120000000
A(02,03) = 5110000000
A(03,03) = 5120000000

HAVE YOU ANY CHANGES, TYPE YES(RCDMK) OR NO(RCDMK)

NO#
E= 5110000000

MATRIX LOADED-WHEN PHASE 2 LOADS, HIT START

E = 2010000000
E = 4910000000
E = 4810000000
E = 4710000000
E = 4610000000
E = 4510000000
E = 4410000000
E = 4310000000
E = 4210000000
E = 4110000000

A(01) = 5134142151
A(02) = 5058578544
A(03) = 5119999993

00011 ROTATIONS.
MAXIMUM AIJ,(I NOT = J), = 3981672426

EIGENVALUES DONE, WHEN PHASE 3 LOADS, HIT START

LOAD PHASE 2 OUTPUT HIT START

V(01,01) = 5050000018
V(02,01) = 5070710712
V(03,01) = 5050000030
V(01,02) = 5050000005
V(02,02) = 5070710699
V(03,02) = 5050000030
V(01,03) = 5070710708
V(02,03) = 5362605540
V(03,03) = 5070710697
END

THIS IS A COMPLETE RECORD OF CONSOLE OPERATIONS FOR THE 1620 EIGENVALUE PROGRAM.
TEST MATRIX 3 X 3 - SWITCHES 1, 2 AND 3 ON. 1620 W/DIVIDE AND INDIRECT ADDRESSING.

310000300002
SS1 ON-DATA ON CARDS, OFF-DATA ENTRY VIA TYP.
SS2 ON-PUNCH ROTATION ANGLES, OFF-NO PUNCH.
SS3 ON-DATA TYPED OUT TO VERIFY, OFF-NO TYPE.
SS4 ON-ERROR ENTERED FROM TYP., OFF-NORMAL.
CLEAR CARD PUNCH AND READY FORMS.
PLEASE LOAD DATA AND HIT START

N= 03 , DELTA = 4110000000
A(01,01) = 5120000000
A(01,02) = 5110000000
A(01,03) = 0000000000
A(02,02) = 5120000000
A(02,03) = 5110000000
A(03,03) = 5120000000

HAVE YOU ANY CHANGES, TYPE YES(RCDMK) OR NO(RCDMK)

NO#

E= 5110000000

MATRIX LOADED-WHEN PHASE 2 LOADS, HIT START

E = 5010000000
E = 4910000000
E = 4810000000
E = 4710000000
E = 4610000000
E = 4510000000
E = 4410000000
E = 4310000000
E = 4210000000
E = 4110000000

A(01) = 5134142153
A(02) = 5058578477
A(03) = 5119999993

00011 ROTATIONS.
MAXIMUM AIJ,(I NOT = J), = 4011832334

EIGENVALUES DONE, WHEN PHASE 3 LOADS, HIT START

LOAD PHASE 2 OUTPUT HIT START

V(01,01) = 5050000020
V(02,01) = 5070710714
V(03,01) = 5050000035
V(01,02) = 5049999999
V(02,02) = 5070710708
V(03,02) = 5050000043
V(01,03) = 5070710722
V(02,03) = 5279476400
V(03,03) = 5070710697

END

PHASE 1

ALL 1620 CARD SYSTEMS

SPS LISTING

19

* THIS IS PHASE 1 - MATRIX LOADER ANY 1620
 *
 00402 16 00420 -7258
 00402 16 00420 -7258
 00414 26 -7258 03115
 00426 11 00419 000-1
 00438 14 00417 000KC
 00450 47 00414 01200
 00462 15 01639 00009
 00474 34 00000 00102
 00486 39 03223 00100
 00498 34 00000 00102
 00510 39 03313 00100
 00522 34 00000 00102
 00534 39 03399 00100
 00546 34 00000 00102
 00558 39 03489 00100
 00570 34 00000 00102
 00582 39 03575 00100
 00594 34 0000L 00102
 00606 39 02277 00100
 00618 34 0000G 00102
 00630 48 00641 00641
 00642 46 00698 00100
 00654 34 00000 00102
 00666 36 03116 00100
 00678 46 00654 00400
 00690 49 00710 00000
 00698
 00698 36 03116 00500
 00710 45 00958 03128
 00722 32 03116 00000
 00734 33 03117 00000
 00746 26 07247 03117
 00758 26 07227 03117
 00770 34 00000 00102
 00782 39 02271 00100
 00794 38 07243 00100
 00806 38 07246 00400
 00818 39 02639 00100
 00830 38 03118 00100
 00842 32 03118 00000
 00854 26 07237 03127
 00866 16 03104 -00000

DCRG 4022
 TFM START&6,07258Z
 START TF 7258,ZERO,2Z
 AM *-7,1,10Z
 CR START&3,20,10Z
 BNZ STARTZ
 TDM SW161,9,, SWITCH 1 OFFZ
 RCTY Z
 WATY MESS1Z
 RCTY Z
 WATY MESS2Z
 RCTY Z
 WATY MESS3Z
 RCTY Z
 WATY MESS4Z
 RCTY Z
 WATY MESS5Z
 RCTY Z
 WATY DATAZ
 RCTY Z
 TMPSTR H TEMP,TEMPZ
 BC1 TAPE,,, ENTRY VIA TYPZ
 RCTY Z
 RNTY I-1Z
 BC4 *-24Z
 B TAPE612Z
 DORG #-3Z
 TAPE RNCD I-1,,, READ N AND DELTAZ
 BNR CNTRLR,1611Z
 SF I-1,,, SET N FLAGZ
 CF I,,, NGZ
 TF E,IZ
 TF N,IZ
 RCTY Z
 WATY NEQUALZ
 WNTY E-IZ
 WNCD E-1,,, PUNCH NZ
 WATY DELTAKZ
 WNTY J-1Z
 SF J-1,,, SET DELTA FLAGZ
 TF DELTA,J68Z
 TFM COUNT,,, COUNT#0Z

20

00878 14 U7227 00ONO
 00890 47 U9993 01100
 0C902 34 00000 00102
 00914 39 U2341 00100
 00926 34 00000 00102
 00938 38 U3116 00100
 00950 49 U0654 00000
 00958
 00958 34 00000 00102
 00970 39 U2541 00100
 00982 49 U0926 00000
 00990
 00990 14 U7227 000-3
 01002 46 U1046 01300
 01014 34 00000 00102
 01026 39 U02441 00100
 01038 49 U0926 00000
 01046
 01046 11 U7247 000-1
 01058 23 U7247 U7227
 01070 26 U7247 00099
 01082 13 U7247 000-5
 01094 26 U1733 00098
 01106 26 U7247 03115
 01118 15 U3130 00000
 01130 46 U1186 00100
 01142 34 00000 00102
 01154 36 U3116 00100
 01166 46 U1142 00400
 01178 49 U1198 00000
 01186
 01186 36 U3116 00500
 01198 45 U1254 03116
 01210 15 U3130 00000
 01221 1
 01222 15 U3116 00000
 01234 15 U1639 00001
 01246 49 U1650 00000
 01254
 01254 45 U2050 03130
 01266 32 U03120 00000
 01278 32 U3118 00000
 01290 32 U3116 00000
 01302 24 U7227 03119
 01314 47 U2050 U1300

CM N,50,10Z
 BNN LESS50Z
 RCTY Z
 WATY BIGZ
 NERR RCTY Z
 WNTY I-1Z
 B TMPSTR&24Z
 DORG #-32
 CNTRLR RCTY Z
 WATY ERRORCZ
 B NERRZ
 DORG #-32
 LESS50 CM N,3+10Z
 BNL SIZEOKZ
 RCTY Z
 WATY SMALLZ
 B NERRZ
 DORG #-32
 SIZEOK AM E,1,10,PLUS 1Z
 M E,N,,N%N&1#Z
 TF E,ACZ
 MM E,5,10,%10/2#%N%N&1#Z
 TF TSTEND&11,AC-1,, SET LND TESTZ
 TF E,ZEROZ
 LOOP TDM INPUT&1,0,, RECORD MARK&0Z
 READ BC1 READ2Z
 RCTY Z
 RNTY INPUT-13Z
 BC4 #-24Z
 B #620Z
 DORG #-32
 READ2 RNCN INPUT-13,,,READZ
 BNR GUT,INPUT-13,, FILE TESTZ
 TDM INPUT&1Z
 DC 1,*#*Z
 TDM INPUT-13,0Z
 TDM SW161,1,,SWITCH 1 NOW 01,Z
 B ASK,,,INQUIREZ
 DORG #-32
 GUT BNR INLARM,INPUT&1,,CHECK RECORDZ
 RCRDOK SF INPUT-9,,,FLAG AIJZ
 SF INPUT-11,,,FLAG JZ
 SF INPUT-13,,,FLAG IZ
 C N,JZ
 BL INLAHZ
 21

01338 27 U3118 03117
 01350 46 U1838 01200
 01362 24 U3128 U7246
 01374 47 U1398 01300
 01386 26 U7247 03129
 01398 26 U0641 03119
 01410 12 U0641 000-3
 01422 23 U0641 03119
 01434 26 U0641 00099
 01446 13 U0641 000-5
 01458 11 00099 -7758
 01470 21 U0098 03117
 01482 32 U0095 00000
 01494 26 U1512 00099
 01506 24 -00000 03115
 01518 46 U1578 01200
 01530 34 00000 00102
 01542 39 U02721 00100
 01554 38 U3116 00100
 01566 12 U3104 000-1
 01578 26 U1596 00099
 01590 26 00000 03129
 01602 47 U1626 00300
 01614 17 U2190 000-0
 01626 11 U3104 000-1
 01638 49 U1118 00000
 01650 34 00000 00102
 01662 39 U2993 00100
 01674 34 00000 00102
 01686 37 U3093 00100
 01698 46 U1674 00400
 01710 45 U2086 03097
 01722 14 U3104 -00000
 01734 47 U2142 01200
 01746 34 00000 00102
 01758 39 U2663 00100
 0177 28 U7238 00100
 01782 34 00000 00102
 01794 34 00000 00102
 01806 39 U3643 00100
 01818 36 00000 00500
 01830 49 U0000 00000
 01838
 01838 14 U3121 U00M5

SL YALRMZ
 BE STORI,,,DOES INJZ
 C INPUT-1,E-1,, AIJ VS EZ
 BL STORIJZ
 TF E,INPUT,,AIJ INTO E IF HIGHERZ
 STORIJ TF TEMP,JZ
 SM TEMP,3,10Z
 M TEMP,J,,JZ-3# TO 4 DIGITSZ
 TF TEMP,AC,, A%AIJ#Z
 MM TEMP,5,10, 5*TEMP-6 DIGITSZ
 PATCH1 AM AC,077582
 A AC-1,1,,& 10*I2
 SF 95,,FIELD NOW 5 DIGITSZ
 TF STORE&6,AC,, SET COMPAREZ
 STORE C 0,ZERO,2, OCCUPIED TESTZ
 BE DIJOBZ
 RCTY Z
 WATY DUP,,,TYPE DUP. ERRORZ
 WNTY INPUT-13Z
 SM COUNT,1,10, COUNT-1Z
 DIJOBZ TF #618,ACZ
 TF 0,INPUT,, STORE IF I NOT # JZ
 BNC3 RETURNZ
 BTM OUTDUP,0,10Z
 RETURN AM COUNT,1,10, COUNT&1Z
 SW1 B LOOP,,,DUMMY - NOPZ
 ASK RCTY Z
 WATY INQUIRZ
 RCTY Z
 RATY ADD,,, YES OR NO ENTERED.Z
 BC4 #-24Z
 BNR INLARM&36,ADD64Z
 TSTEND CM COUNT,,, COUNT VS N%N&1#Z
 BNE CTRWRNGZ
 EXIT RCTY Z
 WATY EQUALZ
 WNTY E-9Z
 RCTY Z
 RCTY Z
 WATY INSTRUCT
 RNCN 00000,,,LOAD PHASE & LOADERZ
 B 00000,,,EXECUTE LOADERZ
 DORG #-32
 STORII CM INPUT-B,45,10, IS AT SMALLZ
 22

01850 46 01898 01100
 01862 34 00300 00102
 01874 39 02679 00100
 01886 38 03116 00100
 C1898 16 01928 -7248
 C1910 21 01927 03117
 01922 24 -C000 03115
 01934 46 01994 01200
 C1946 34 00300 00102
 01958 39 02721 00100
 01970 38 03116 00100
 01982 12 03104 000-1
 01994 26 02012 01928
 02006 26 -0000 03129
 02018 47 02042 00300
 02030 17 02190 000-0
 02042 49 01626 00000
 02050
 02050 34 00000 00102
 02062 15 03139 00000
 02073 1
 02074 38 03116 00100
 02086 39 02793 00100
 02098 34 00000 00102
 02110 36 03116 00100
 02122 46 02098 00400
 02134 49 01198 00000
 02142
 02142 34 00000 00102
 02154 39 02893 00100
 02166 38 03100 00100
 02178 49 01650 00000
 02190 25 03203 03116
 02202 25 03205 03117
 02214 25 03209 03118
 02226 25 03211 03119
 02238 34 00000 00102
 02250 39 03197 00100
 02262 38 03120 00100
 02274 42 00000 00000

N

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SM I1OKZ
 RCTY Z
 WATY IILARMZ
 WNTY INPUT-13Z
 IIOK TF *E30,DIAG-10,, ABAILHZ
 A *E17,I,, L=AI10#DIAG610*IZ
 C 01ZEKO2,, OCCUPIED TLSTZ
 RE EULSKAZ
 RCTY Z
 WATY DWPZ
 WNTY INPUT-13,, BAD RECORDZ
 SM COUNT,1,10Z
 EDESKA TF #S18,IICK&30Z
 TF OINPUT+2,, STORE AIZ
 BNCB #624Z
 BTM OUTDUP,0,10Z
 B RETURNZ
 DORG #-3Z
 INLARM RCTY Z
 TDM INPUT&10,,, INSURANCE RMZ
 DC 1,@,*Z
 WNTY INPUT-13Z
 WATY RCWRNG,,, BAD RECORDZ
 RCTY Z
 RNTY INPUT-13,,, CORRECT RECORDZ
 BC4 *E24Z
 B READ2612Z
 DORG *E3Z
 CTWRNG RCTY Z
 WATY NUMBERZ
 WNTY COUNT-4Z
 B ASK,,, ENTER MISSING RECORDZ
 OUTDUP TD OUTTYP66,I-1Z
 TD OUTTYP68,IZ
 TD OUTTYP612,J-1Z
 TD OUTTYP614,JZ
 RCTY Z
 WATY OUTTYPZ
 WNTY INPUT-9Z
 BB Z

P

02276 DORG #-9Z
 * PHASE 1 CONSTANTS2
 07758 1225 00010 ELEMNT DSB 1225,10,7758Z
 07258 50 00010 DSB 50,10,07258Z
 02277 32 DATA DAC 32,PLEASE LOAD DATA AND HIT START@Z
 02361 50 BIG DAC 50,MATRIX TOO LARGE,RE-ENTER CONTROL RECORD VIA TYP.@Z
 02441 50 SMALL DAC 50,MATRIX TOO SMALL,RE-ENTER CONTROL RECORD VIA TYP.@Z
 02541 49 ERRORC DAC 49,CONTROL RECORD ERROR,RE-ENTER VIA TYPEWRITER NOW@Z
 02639 12 DELTAK DAC 12,, DELTA # @Z
 02663 4 EQUAL DAC 4,E# @Z
 02671 4 NEQUAL DAC 4,N# @Z
 02679 21 IILARM DAC 21,SINGULARITY POSSIBLE@Z
 02721 36 DUP DAC 36,IJ DUPLICATED, RECORD USED WILL BE @Z
 02793 50 RCWRNG DAC 50,DATA ERR OR ADDITION,INSERT VIA TYPEWRITER NOW @Z
 02893 50 NUMBER DAC 50,COUNT WRONG,YOUR ANSWER MUST BE YES TO QUERY @Z
 C2993 50 INQUIR DAC 50,HAVE YOU ANY CHANGES,TYPE YES@RCDMK# OR NO@RCDMK@#Z
 03093 4 ADD DAC 4,NOX@Z
 03104 5 COUNT DS 5Z
 03105 1 RM DC 1,@Z
 00641 10 TEMP DS 10,TMPSTR&11Z
 03115 1 ZERO DC 10,-0Z
 03117 2 I DS 2Z
 03119 2 J DS 2Z
 03129 10 AIJ DS 10Z
 07227 2 N DS 2,7227Z
 07237 1v DELTA DS 10,7237Z
 07247 10 E DS 10,7247Z
 07248 1 XYZ DC 1,@,7248Z
 03129 INPUT DS ,AIJZ
 03195 66 CARDIN DS 66Z
 03143 1 INSURE DC 1,@,INPUT614Z
 00U99 AC DS ,99Z
 03197 13 OUTTYP DAC 13, A\$00,000 # @Z
 03223 45 MESS1 DAC 45,SS1 ON-DATA ON CARDS,OFF-DATA ENTRY VIA TYP.@Z
 03313 43 MESS2 DAC 43,SS2 ON-PUNCH ROTATION ANGLES,OFF-NO PUNCH@Z
 03399 45 MESS3 DAC 45,SS3 ON-DATA TYPED OUT TO VERIFY,OFF-NO TYPE@Z
 03489 43 MESS4 DAC 43,SS4 ON-ERROR ENTERED FROM TYP.,OFF-NORMAL@Z
 03575 34 MESS5 DAC 34,CLEAR CARD PUNCH AND READY FORMS@Z
 03643 44 INSTRC DAC 44,MATRIX LOADED-WHEN PHASE 2 LOADS, HIT START@Z
 03402 DEND START-12Z

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PHASE 2
BASIC 1620 CARD SYSTEMS
SPS LISTING

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* THIS IS PHASE 2 - EIGENVALUES COMPUTE BASIC 1620 Z
* Z
ENTRY TDM 401,1,9Z
        TFM IKUDA-1,0Z
START TFM 1,1,10, I#1Z
        TFM J,2,10, J#2Z
        TFM CMPARE66,7751,, SET SEARCHZ
I1J1 TDM SW161,1,, 1 OFFZ
CMPARE C 7751,E-7,2,,LESS THAN EZ
BL STEPI,,, ****NO HITZ
HIT TDM SW161,9,, 1 ONZ
        TFM IADDG11,7248,, SET 1 ADDZ
A IADD610,I,, AII ADDZ
IADD TF AII,0Z
        TFM JADD610,07246Z
A JADD610,J,, AJAJJZ
JADD TF AJJ,0Z
        TF *635,CMPARE66Z
AM #6237,10, AIJ ADDZ
AIJADD TF AIJ,0Z
        TF AIMIAJ,AIJZ
FS AIMIAJ,AJJ,, AI-AJZ

BNZ SKIP2Z
TF NEWAIJ,ZEROZ
TD TEMP,AIJZ
B FORMAIZ
DORG #-3Z
SKIP2 TF AC,AIMIAJZ
FA AC,AC,, 2%AI-AJZ

FD AIJ,ACZ

ANGLET C 96,TAN225,, ALPHA TO TAN 22.5Z
BL SINCOSS,, JUMP IF ALPHA SMALLZ
TD TEMP,AC,, ALPHA SIGNZ
FM AIMIAJ,HALFZ

TF NEWAIJ,AC,, AIJZ
FORMAI TF NEWAIJ,AJJZ

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02666 16 00469 -2701
 02678 16 00445 -6213
 02690 49 00422 -6167
 02702 16 00469 -2737
 02714 26 01260 06213
 02726 49 01262 -6087
 02738 26 06213 00099
 02750 26 06223 06213
 02762 16 00469 -2797
 02774 16 00445 -6213
 02786 49 00402 -6187
 02798 16 00469 -2833
 02810 16 00445 -6223
 02822 49 00422 -6187
 02834 15 04567 00009
 02846 15 05987 00000
 02857 1 05986 00008
 02858 44 02902 06250
 02870 15 05986 00000
 02882 15 05247 00001
 02894 49 04046 00000
 02902
 02912 15 05986 00008
 02926 26 06250 06213
 02938 26 06213 06223
 02950 26 06223 06250
 02962 44 02994 06233
 02974 33 06233 00000
 02986 49 04046 00000
 02994
 02994 32 06233 00000
 03006 49 04046 00000
 03014
 03014 26 06311 00099
 03026 16 00469 -3061
 03038 16 00445 -0099
 03050 49 00422 -0099
 03062 26 06301 00099
 03074 16 00469 -3109
 03086 26 01260 06311
 03098 49 01262 -6311
 03110 26 06005 00099
 03122 16 00469 -3157
 03134 16 00445 -0099

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FA NEWAII, AIJZ
 FM NEWAII, HALFZ
 TF NEWAII, ACZ, 1/2WAIGAJDZ
 TF NEWAJJ, NEWAIIZ
 FS NEWAII, AIJZ

FA NEWAJJ, AIJZ

TDM SW261,9,, SW2 ONZ
 TDM J&2Z
 DC 1,*@,*Z
 BNF PLUS,TEMP,, IS ALPHA-Z
 MINUS TDM J&18,11Z
 TDM SW361,1,, SW3 OFFZ
 B STOREZ
 DORG *-32

PLUS TDM J61,8Z
 TDM SW361,9,, SW3 ONZ
 TF TEMP,NEWAIIZ
 TF NEWAII, NEWAJJZ
 TF NEWAJJ, TEMP,, SWITCH AI-AJZ
 BNF *632,NEWAIJZ
 CF NEWAIJ,,, INVERT AIJ SIGNZ
 B STOREZ
 DORG *-32
 SF NEWAIJZ
 B STOREZ
 DORG *-32

SIN COS TF SC,AC,, GAMMAZ
 FA AC,AC,, 2 GAMMAZ

TF S2,ACZ
 FM SC,SCZ

TF C0S,AC,, GAMMA**2Z
 FA AC,ONE,, 1&GAMMA**2Z

03146 49 00422 -6077
 03158 26 06250 00099
 03170 16 00469 -3205
 03182 26 01260 06301
 03194 49 01422 -6250
 03206 26 05995 00099
 03218 26 06260 06077
 03230 16 00469 -3265
 C3242 16 00445 -6260
 03254 49 00402 -6005
 03266 16 00469 -3301
 03278 26 01260 0626C
 03290 49 01422 -6250
 03302 26 06005 00099
 03314 16 00469 -3349
 03326 26 01260 06005
 03338 49 01262 -6035
 03350 26 06321 00099
 03362 26 06301 06077
 03374 16 00469 -3409
 03386 16 00445 -6301
 03398 49 00402 -6321
 C341J 16 00469 -3445
 C3422 26 01260 05995
 03434 49 01262 -60305
 03446 26 06311 00099
 03458 16 00469 -3493
 03470 26 01260 06311
 03482 49 01262 -6197
 03494 26 06250 00099
 03516 26 00L99 06321
 03518 16 00469 -3553
 03530 16 00445 -0099
 03542 49 00402 -6301
 03554 16 00469 -3589
 03566 26 01260 00099
 03578 49 01262 -6187
 03581 16 00469 -3625
 03602 16 00441 -0099
 03614 49 00402 -6250
 03626 26 06233 00099
 03638 16 00469 -3673
 03650 26 01260 06311
 03662 49 01262 -6187
 03674 16 00469 -3700

FA SIN,COSZ
 AAA TF SC,ACZ
 FM SC,AIMIAJ,, SC8AII-AJJDZ

TF TEMP,ACZ
 TF AC,C2Z
 FS AC,S2Z

FM AC,AIJZ

FS AC,TEMPZ

TF NEWAIJ,ACZ
 FM SC,AI'Z

FA AC,ACZ

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03686	16	00445	-0090	
03698	49	00422	-0099	
03710	26	00260	00099	TF
03722	16	00469	-3757	FM
03734	26	01260	00321	TEMP2,ACZ, C2,AIJZ
03746	49	01260	-6167	
03758	26	00213	00099	TF
03770	16	00469	-3805	FM
03782	26	01260	00301	NEWAI1,ACZ S2,AJJZ
03794	49	01262	-6177	
03806	16	00469	-3841	FA
03818	16	00445	-6213	
03830	49	00422	-0099	
03842	16	00469	-3877	FA
03854	16	00445	-6213	
03866	49	00422	-6260	
03878	16	00469	-3913	FM
03890	26	01260	00301	S2,AIJZ
03902	49	01262	-6167	
03914	26	00223	00099	TF
03926	16	00469	-3961	FM
03938	26	01260	00321	NEWAJJ,ACZ C2,AJJZ
03950	49	01262	-6177	
03962	16	00469	-3997	FA
03974	16	00445	-6223	
03986	49	00422	-0099	
03998	16	00469	-4033	FS
04010	16	00445	-6223	
04022	49	00402	-6260	
04034	15	04567	00001	STORE
04046	26	00406	02357	TF SW2,1,, SW2 OFFZ
04058	26	00000	06223	TF *618,JADD611Z
04070	26	00408	02393	TF 00000,NEWAJJ,, STORE AJJZ
04082	26	00000	06233	TF *618,AIJADD611Z
04094	26	04112	02321	TF 00000,NEWAIJ,, STORE AIJZ
04106	26	00000	06213	TF *618,IADD511Z
04118	26	02282	07227	TF 00000,NEWAI1,, STORE AI1Z
04130	11	06202	-0001	ROTATE TF K,N,, K#N
04142	24	02282	05983	AM IKUDA-1,1,, STEP COUNTZ
04154	47	04210	01300	C K,IZ
04166	46	04866	01200	BL SWCHIK,,, K LESS THAN IZ
04178	26	02284	02282	BE SKIP,,, K#I
04190	26	02246	05983	TF K1,K,, K GREATER THAN IZ
04202	49	04234	00000	TF 11,IZ
04210				B AAIKZ
				DORG #-32

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04210	26	02284	05983	SWCHIK TF K1,I,, K LESS THAN IZ
04222	26	02246	02282	TF I1,KZ
04234	26	06250	02284	TF TEMP,K1Z
04246	12	06250	000-3	SM TEMP,3,10Z
04258	23	06250	02284	M TEMP,K1,, K#K-3HZ
04270	26	06250	00099	TF TEMP,ACZ
04282	13	06250	000-5	MM TEMP,5,10,, 6 DIGITSZ
04294	11	00099	-7758	AM AC,07758Z
04306	21	00098	02246	A AC-1,11,, AAIKHZ
04318	32	00095	00000	SF AC-6Z
04330	26	04353	00099	TF AIKADD611,ACZ
04342	26	06213	00000	AIKADD TF AIK,OZ
04354	24	02282	05985	C K,JZ
04366	47	04422	01300	BL SWCHJKZ
04378	46	04866	01200	BE SKIPZ
04390	26	02248	05985	TF J1,J,, K GREATER THAN JZ
04402	26	02284	02282	TF K1,KZ
04414	49	04446	00000	B AAJKZ
04422				DORG #-32
04422	26	02248	02282	SWCHJK TF J1,K,, K LESS THAN JZ
04434	26	02284	05985	TF K1,JZ
04446	26	06250	02284	AAJK TF TEMP,K1,, AJK ADDZ
04458	12	06250	000-3	SM TEMP,3,10Z
04470	23	06250	02284	M TEMP,K1Z
04482	26	06250	00099	TF TEMP,ACZ
04494	13	06250	000-5	MM TEMP,5,10,, 6 DIGITSZ
04506	11	00099	-7758	AM AC,07758Z
04518	21	00098	02248	A AC-1,J1Z
04530	32	00095	00000	SF AC-6Z
04542	26	04565	00099	TF AJKADD611,ACZ
04554	26	06223	00000	AJKADD TF AJK,OZ
04566	49	05078	00000	SW2 B DEG45Z
04578	16	00469	-4613	FM COS,AIKZ
04590	26	01260	06005	
04602	49	01262	-5213	TF TEMP2,ACZ
04614	26	06260	00099	FM SIN,AIKZ
04626	16	00469	-4661	
04638	26	01260	05995	
04650	49	01262	-6223	
04662	16	00469	-4697	FA TEMP2,ACZ
04674	16	00445	-6260	
04686	49	00422	-0099	
04698	16	00469	-4733	
04710	26	01260	05995	
04722	49	01262	-6213	FM SIN,AIKZ

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04734 26 06250 00099
 04746 16 00469 -4781
 04758 26 01260 06005
 04770 49 01262 -6223
 04782 16 00469 -4817
 04794 16 00445 -0099
 04806 49 00402 -6250
 04818 26 04836 04565
 04830 26 00000 00099
 04842 26 04860 04353
 04854 26 00000 06260
 04866 12 02282 000-1
 04878 47 04142 01200
 04890 47 04914 02000
 04902 38 05982 04000
 04914 11 05983 000-1
 04926 24 05983 05985
 04938 47 05370 01200
 04950 24 05985 07227
 04962 47 05346 01300
 04974 49 02202 00000
 04986 24 07246 07236
 04998 47 05390 01100
 05010 12 07239 000-1
 05022 34 00000 00102
 05034 39 06419 00100
 05046 38 07238 00100
 05058 46 05390 01200
 05070 49 02202 00000
 05078 16 00469 -5113
 05090 26 01260 06489
 05102 49 01262 -0213
 05114 26 06250 00099
 05126 16 00469 -5161
 05138 26 01260 06489
 05150 49 01262 -6223
 05162 26 06260 06250
 05174 16 00469 -5209
 05186 16 00445 -6260
 05198 49 00422 -0099
 05210 16 00469 -5245
 05222 16 00445 -0099
 05234 49 00402 -6250
 05246 49 04818 00000
 TF TEMP,AC,, AIK*SINZ
 FM COS,AJKZ
 FS AC*TEMPZ
 RTSTOR TF *618,AJKADD611Z
 TF 0,AC,, AJK STOREDZ
 TF #618,AIKADD611Z
 TF 0,TEMP2,, AIK STORLDZ
 SKIP SM K=1,1C, K-1Z
 BNZ ROTATE624,,, RETURNZ
 WANTU BNC2 STEP1,,, SKIP PUNCHZ
 WNCD I-1,,, PUNCH I,J,SIN,COSZ
 STEP1 AM I,1,10, 161Z
 C I,JZ
 BNE RESET2Z
 C J,N,, J VS NZ
 BL RESET2-24Z
 SW1 B START,,, SOMETIMES NOPZ
 C E-1,DELTA-1,, E VS DELTAZ
 BNH TYPOUTZ
 SM E-8,1,10, E/E/10Z
 RCTY Z
 WATY EQUALZ
 WNTY E-9Z
 BZ TYPOUTZ
 B STARTZ
 DORG #-32
 DEG45 FM SQRTZ,AIKZ
 TF TEMP,ACZ
 FM SQRTZ,AJKZ
 TF TEMP2,TEMPZ
 FA TEMP2,AC,, AIKZ
 FS AC*TEMP,, AJKZ
 SW3 B RTSTOR,,, NOPZ

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05258 26 06250 06260
 05270 26 06260 00099
 05282 26 00099 06250
 05294 44 05326 06260
 05306 33 06260 00000
 05318 49 04818 00000
 05326 32 06260 00000
 05338 49 04818 00000
 05346 16 05983 000-1
 05358 11 05985 000-1
 05370 11 02255 000-1
 05382 49 02250 00000
 05390 34 00000 00102
 05402 34 00000 00102
 05414 16 05983 000-1
 05426 16 05497 -7258
 05438 25 06437 05982
 05450 25 06439 05983
 05462 34 00000 00102
 05474 39 06429 00100
 05486 26 06005 07258
 05498 33 05996 00000
 05510 38 05996 00100
 05522 11 05983 000-1
 05534 11 05496 000-1
 05546 24 05983 07227
 05558 47 05438 01100
 05570 34 00000 00102
 05582 34 00000 00102
 05594 38 06198 00100
 05606 39 06455 00100
 05618 26 06250 07227
 05630 12 06250 000-3
 05642 23 06250 07227
 05654 26 06250 00099
 05666 13 06250 000-5
 05678 11 00099 -7748
 05690 21 0598 07227
 05702 32 00095 00000
 05714 26 05821 00099
 05726 26 06005 00097
 05738 16 05761 -7758Z
 TF TEMP,TEMP2,, SWITCH AIK-AJKZ
 TF TEMP2,ACZ
 TF AC*TEMPZ
 BNF SETF,TEMP2Z
 CF TEMP2Z
 B RTSTORZ
 DORG #-32
 SF TEMP2,,, INVERT AIK SIGNZ
 B RTSTORZ
 DORG #-32
 TFM I,1,10, 1#1Z
 AM J,1,10, J#1Z
 RESET2 AM CMPARE65,1,10, AIJ&1Z
 B CMPARE,,, LOOP BACKZ
 DORG #-32
 TYPOUT RCTY Z
 RCTY Z
 TFM I,1,10, 1#1Z
 TFM VAR611,DIAGZ
 AGAIN TD OUTPUT68,I-1,, SET INDEXZ
 TD OUTPUT&10,1Z
 RCTY Z
 WATY OUTPUTZ
 VAR TF COS,DIAGZ
 CF COS-9Z
 WNTY COS-9Z
 AM I,1,10, 1#1Z
 AM VAR610,1,10, STEP FETCHZ
 C I,N,, I VS NZ
 BNH AGAINZ
 RCTY Z
 RCTY Z
 WNTY IKUDA-5,,, TYPE ROTATIONSZ
 WATY CNTZ
 TF TEMP,NZ
 SM TEMP,3,10Z
 M TEMP,N,, N%N-3#Z
 TF TEMP,ACZ
 MM TEMP,5,10Z
 AM AC,07748Z
 A AC-1,NZ
 SF AC-4Z
 TF ENDSUR&11,ACZ
 TF COS,ZEROZ
 TFM CHANGE&11,07758Z

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05750	26	05250	00000
05762	24	06004	06249
05774	46	05798	01100
05786	26	06005	06250
05798	11	05769	000-1
05810	14	05761	-0000
05822	47	05750	01100
05834	34	00000	00102
05846	39	06199	00100
05858	38	05996	00100
05870	15	05982	00000
05881			1
05882	38	05982	00400
05894	34	00000	00102
05906	34	00000	00102
05918	46	05950	00200
05930	39	06263	00100
05942	49	05962	00000
05950			
05950	39	06323	00100
05962	36	00000	00500
05974	49	00000	00000
05982			
07758		1225	00010
07258		50	00010
07247		10	
07248		1	
07237		10	
07227		2	
05983		2	
05985		2	
05995		10	
C6005		10	
C6006		1	
C6009		30	
02246		2	
02248		2	
02284		2	
02282		2	
06077		10	
06087		10	
06097		10	
06099		30	
06167		10	

PHASE 2 CONSTANTSZ

ELEMNT	DSD	1225,10,7758Z
DIAG	DSD	50,10,7258Z
L	DS	10,7247Z
RM2	DC	1,3,7248Z
DELTA	DS	10,7237Z
N	DS	2,7227Z
I	DS	22
J	DS	22
SIN	DS	10Z
COS	DS	10Z
HM	DC	1,0Z
CMPATE	DAC	30,LOAD PHASE 2 OUTPUT-HIT STARTZ
I1	DS	2,11J168Z
J1	DS	2,11J1610Z
K1	DS	2,HIT&10Z
K	DS	2,HIT&8Z
ONE	DC	10,5110000000Z
HALF	DC	10,5050000000Z
ZERO	DC	10,0Z
MESS2	DAC	30,MAXIMUM AIJ,%I NOT # J0, # @Z
AII	DS	10Z

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06177		10	AIJ	DS	10Z
06187		10	AIJ	DS	10Z
06197		10	AIM1AJ	DS	10Z
06203		6	IKUDA	DC	6,0EZ
06213		10	NEWAIJ	DC	10,0Z
06223		10	NEWAJJ	DC	10,0Z
06233		10	NEWA1J	DC	10,0Z
06240		7	TAN225	DC	7,5041421Z
06250		10	TEMP	DS	10Z
06260		10	TEMP2	DS	10Z
00099			AC	DS	*99Z
06263		15	END	DAC	15,END OF PROGRAMZ
06301		10	S2	DS	10Z
06311		10	SC	DS	10Z
06321		10	C2	DS	10Z
06213		10	AIK	DS	10,NEWAIIZ
06223		10	AJK	DS	10,NEWAJJZ
06323		48	PHASE3	DAC	48,EIGENVALUES DONE. WHEN PHASE 3 LOADS, HIT STARTZ
06419		5	EEQUAL	DAC	5,E # @Z
06429		13	OUTPUT	DAC	13, A#000 # @Z
06455		13	CNT	DAC	13, ROTATIONS.@Z
06489		10	SQRT2	DC	10,5070710678Z
02178			DEND	ENTRYZ	

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PHASE 3

BASIC 1620 CARD SYSTEMS

SPS LISTING

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* TH IS I S PHASE 3.- EIGENVECTOR COMPUTE BASIC CARD 1620 Z

02178 15 02419 00-01
 02190 16 02427 000-1
 02202 34 00000 00102
 02214 34 00000 00102
 02226 39 03859 00100
 02238 34 00000 00102
 02250 34 00000 00102
 02262 48 02273 02273
 02274 16 02429 000-1
 02286 16 02304 -4008
 02298 26 04008 03957
 02310 11 02303 000-1
 02322 14 02301 000K0
 02334 47 02298 01200
 02346 16 02364 -4008
 02358 26 04008 03947
 02370 11 02363 000L3
 02382 14 02364 J4238
 02394 47 02358 01100
 02406 36 03828 00500
 02418 49 02626 00000
 02430 16 02993 000-1
 02442 14 03829 000L2
 02454 46 02946 01100
 02466 26 03165 03829
 02478 16 02865 -3678
 02490 13 03829 000L3
 02502 21 02864 00099
 02514 15 03003 00091
 02526 26 02889 03829
 02538 49 02722 000G0
 02546
 02546 16 03165 000L2
 02558 16 02865 -3998
 02570 13 03829 000L2
 02582 21 02864 00099
 02594 16 02889 000L2
 02606 15 03003 00099
 02618 49 02722 00000
 02626
 02626 26 03165 03829
 02638 12 03165 000L2

ENTRY TDM SW161,1,9, 1 OFFZ
 TFM OUTI,1,10, I#1Z
 RCTY Z
 RCTY Z
 WATY MESSGEZ
 RCTY Z
 RCTY Z
 HALT H TEMP,TEMPZ
 TFM OUTJ,1,10Z
 CLEAR TFM SETI66,MATRIXZ
 SETI TF MATRIX,ZEROZ
 AM #-7,1,10, DATA AREA#0Z
 CM SETI63,20,10Z
 BNE SETIZ
 ALISET TFM ALLI66,MATRIX,, 18-32Z
 ALLI TF MATRIX,ONE,, 18-32Z
 AM #-7,33,10, 18-32Z
 ALLI2 CM ALLI66,14238,, 18-32Z
 BNH ALLIZ
 READN RNCD N-1Z
 SW1 B PASS2FZ
 TFM ISET611,1,10, SET 1Z
 CM N,32,10Z
 BH OVER32Z
 UNDR33 TF FUNCTN,NZ
 TFM LSTRCD,MATRIX-330Z
 MM N,33,10Z
 A LSTRCD-1,ACZ
 TDM SW261,1,, 2 OFFZ
 TF ICMPAR611,NZ
 B READZ
 DORG #-3Z
 OVER32 TFM FUNCTN,32,10Z
 TFM LSTRCD,MATRIX-10Z
 MM N,32,10Z
 A LSTRCD-1,ACZ
 TFM ICMPAR611,32,10Z
 TDM SW261,9,, 2 ONZ
 B READZ
 DORG #-3Z
 PASS2F TF FUNCTN,NZ
 SM FUNCTN,32,10Z

02650	18	02865	-3398		TFM	LSTRCD,MATRIX-050Z
02662	13	03829	000L3		MM	N,33,10Z
02674	21	02864	00099		A	LSTRCD-1,ACZ
02686	15	03003	00001		TUM	S#261,1,, Z OFFZ
02698	26	02889	03829		TF	ICMPAK611,NZ
02710	16	02993	000L3	READ	TFM	ISET611,33,10, SET 332
02722	36	03832	005C0		KND	I-1,,, READ I,J,S,CZ
02734	45	03106	03832		BNR	COMPUT,I-1Z
02746	16	02841	-4008	TYPEV	TFM	OUT611,MATRIXZ
02758	25	03965	02426		TD	TYPE66,OUT1-1Z
02770	25	03967	02427		TD	TYPE68,OUT1Z
02782	25	03971	02428		TD	TYPE612,OUTJ-1Z
02794	25	03973	02429		TJ	TYPE614,OUTJZ
02806	34	00000	0C102		RCTY	Z
02818	39	03959	00100		WATY	TYPEZ
02830	26	03855	04008	OUT	TF	COS,MATRIX,, TYPE VIJZ
02842	38	03846	00100		WNTY	CUS-9Z
02854	14	02841	-00000	TEST	CM	OUT611,,, LAST RECORDZ
02866	46	03002	01200		BE	SWZZ
02878	14	02427	-00000	ICMPAR	CM	OUT1,,, N OR 32Z
02890	46	02934	01300		BNL	JSETZ
02902	11	02427	000-1		AM	OUT1,1,10, I61Z
02914	11	02840	000-1		AM	OUT610,1,10Z
02926	49	02758	00000		B	TYPEV&12Z
02934					DORG	*-3Z
02934	11	02429	000-1	JSET	AM	OUTJ,1,10, J61Z
02946	16	02841	-3688		TFM	OUT611,MATRIX-320Z
02958	13	02429	000L2		MM	OUTJ,32,10Z
02970	21	02840	00099		A	OUT610,ACZ
02982	16	02427	-00000	ISET	TFM	OUT1,,, 1 OR 33Z
02994	49	02758	00000		B	TYPEV&12Z
03002					DORG	*-3Z
03002	49	03050	00000	SW2	b	PASS2Z
03014	34	00000	C0102		RCTY	Z
03026	39	03989	00100		WATY	PAUMSGZ
03038	48	03049	03049	TRICK	H	TRICK2,TRICK2,, ENDZ
03050	15	02419	000G9	PASS2	TDM	Sw161,9,, 1 ONZ
03062	16	02427	000L3		TFM	OUT1,33,10, I#33Z
03074	16	02357	J4248		TFM	ALISET611,MATRIX&10240Z
03086	16	02393	J9858		TFM	ALLI2611,19858Z
03098	49	02202	00000		B	ENTRY&24Z
03106					DORG	*-3Z
03106	16	03213	-3688	COMPUT	TFM	VKIADD611,MATRIX-320Z
03118	13	03833	000L2		MM	I=32,10,A%A1J#320%I-1#6MATRIXZ
03130	21	03212	00099		A	VKIADD610,ACZ

03142	26	03797	03213	ADDF	TF	END611,VKIADD611Z
03154	11	03796	-3165		AM	END610,FUNCTNZ
03166	16	03225	-3688		TFM	VKJADD611,MATRIX-320Z
03178	13	03835	000L2		MM	J,32,10,A%A1J#320%J-1#6MATRIXZ
03190	21	03224	00099		A	VKJADD610,ACZ
03202	26	03927	00000	VKIADD	TF	VKI,,, STORE VKIZ
03214	26	03937	00000	VKJADD	TF	VKJ,,, STORE VKJZ
03226	45	03474	03837		BNR	HRDWAY,J62,, THETA NOT 45 DEGZ
03238	25	03049	03836		TD	TRICK2,J61,, B OR FLAG BZ
03250	26	02273	03927		TF	TEMP,VKIZ
03262	16	00469	-3297		FA	TEMP,VKIJ,, VKI&VKJZ
03274	16	00445	-2273			
03286	49	00422	-3937	FM	"TEMP,SQRT2Z	
03298	16	0C469	-3333			
03310	26	01260	02273	TF	TEMP,ACZ	
03322	49	01262	-3827	FS	VKJ,VKIZ	
03334	26	02273	00099			
03346	16	00469	-3381	FM	VKJ,TRICK2,, DIFFERENCEZ	
03358	16	00445	-3937			
03370	49	00402	-3927	NEGTV	BNF	STORE,J61Z
03382	16	00469	-3417		TF	VKI,ACZ
03394	26	01260	03937		TF	AC,TEMPZ
03406	49	01262	-3049		TF	TEMP,VKIZ
03418	44	03714	03836		B	STOREZ
03430	26	03927	00099		DORG	*-3Z
03442	26	00099	02273	HRDWAY	FM	VKI,COS,, VKI*COSZ
03454	26	02273	03927			
03466	49	03714	00000	TF	TEMP,ACZ	
03474	16	00469	-3509		FM	VKJ,SINZ
03486	26	01260	03927			
03498	49	01262	-3855	FA	TEMP,AC,,VKI*C6VKJ*S#VKJZ	
03510	26	02273	00099			
03522	16	00469	-3557	FM	VKI,SINZ	
03534	26	01260	03937			
03546	49	01262	-3845	TF	VKI,ACZ	
03558	16	00469	-3593		FM	VKJ,COSZ
03570	16	00445	-2273			
03582	49	00422	-0099			
03594	16	00469	-3629			
03606	26	01260	03927			
03618	49	01262	-3845			
03630	26	03927	00099			
03642	16	00469	-3677			
03654	26	01260	03937			

03666	49	U1262	-3855	
03678	16	U0469	-3713	
03690	16	U0445	-0099	
03702	49	U0402	-3927	
03714	26	J3732	03213	STORE
03726	26	U0030U	02273	TF
03738	26	U3756	03225	,TF
03750	26	U0030U	03099	*#18, STORE VKIZ
03762	11	U3212	000-1	TF
03774	11	J3224	000-1	*#18, STORE VKJZ
03786	14	J3213	-J000	AM
03798	47	U3202	01200	VKIADD610,1,10, 161Z
03810	49	U2722	00000	AM
03818				VKJADD610,1,10, J61Z
				END CM VKIADD&11,,, TEST ENDZ
				BNE VKIADDZ
				B READZ
				DORG *-32
				*
				PHASE 3 CONSTANTS
				*
				Z
00099				AC DS ,99Z
03049	10			TRICK2 DC 10,-5070710678,TRICK611Z
03827	10			SQRT2 DC 10,5070710678Z
02273				TEMP DS #HALT611Z
03829	2			N DS 2Z
C3830	1			RM DC 1@Z
03831	1			DUMMY DS 1Z
03833	2			I DS 2Z
03835	2			J DS 2Z
03845	10			SIN DS 10Z
03855	10			COS DS 10Z
03856	1			RM2 DC 1@Z
03859	3u			MESSGE DAC 30,LOAD PHASE 2 OUTPUT HIT START@Z
03927	10			VKI DS 10Z
03937	10			VKJ DS 10Z
02427	2			OUTI DS 2,SW169Z
02429	2			OUTJ DS 2,SW1611Z
03165	5			FUNCTN DS 5,ADD611Z
02865	5			LSTKCD DS 5,TEST611Z
03947	10			ONE DC 10,5110000000Z
03957	10			ZERO DC 10,-0Z
03959	18			TYPE DAC 15, V800,000 # .0Z
03989	4			PAUMSG DAC 4,END@Z
04008		1600 00010		MATRIX DSB 1600,10,04008Z
02178				DEND ENTRYZ

PHASE 2

1620 CARD SYSTEMS WITH DIVIDE AND INDIRECT ADDRESSING

SPS LISTING

* PHASE 2 - EIGENVALUES COMPUTE 1620 W/DIV & IDA Z
 ENTRY TDM 401,1,92
 TFM IKUDA-1,0Z
 START TFM 1,1,10, 1#1Z
 TFM J,210, J#22
 TFM CMPAKE66,7751,, SET SEARCHZ
 I1J1 TDM SW161,1,, 1 OFFZ
 CMPARE C 7751,E-7,2,, LESS THAN EZ
 HL STEPI,,, ***NO HITZ
 HIT TDM SW161,9,, 1 ONZ
 TFM IADD611,7248,, SET I ADDZ
 A IADD610,I,, AII ADDZ
 IADD TF AII,0Z
 TFM JADD611,07248Z
 A JADD610,J,, A\$AJJZ
 JADD TF AJJ,0Z
 TF #635,CMPARE66Z
 AM #623,7,10, AIJ ADDZ
 AIJADD TF AIJ,0Z
 TF AIMIAJ,AIJZ
 FS AIMIAJ,AJJ,, AI-AJZ

 BNZ SKIP2Z
 TF NEWAIJ,ZEROZ
 TD TEMP,AIJZ
 B FORMAJZ
 DORG #-3Z
 SKIP2 TF AC,AIMIAJZ
 FA AC,AC,, 2\$AI-AJZ

 FD AIJ,ACZ

 ANGLET C 96,TAN229,, ALPHA TO TAN 22.9Z
 BL SINCOS,,, JUMP IF ALPHA SMALLZ
 TD TEMP,AC,, ALPHA SIGNZ
 FM AIMIAJ:HALFZ

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-02630 49 01262 -6027
 02642 26 06173 00099
 02654 26 06153 06117
 02666 16 00469 -2701
 02678 16 00445 -6153
 02690 49 00422 -6107
 02702 16 00469 -2737
 02714 26 01260 06153
 02726 49 01262 -6027
 02738 26 06153 00099
 02750 26 06163 06153
 02762 16 00469 -2797
 02774 16 00445 -6153
 02786 49 00402 -6127
 02798 16 00469 -2833
 02810 16 00445 -6163
 02822 49 00422 -6127
 02834 15 04531 00009
 02846 15 05927 00000
 02857 1
 02858 44 02902 06190
 02870 15 05926 00000
 02882 15 05187 00001
 02894 49 04046 00000
 02902 15 05926 00008
 02914 15 05187 00009
 02926 26 06190 06153
 02938 26 06153 06163
 02950 26 06163 06190
 02962 44 J2994 06173
 02974 33 06173 00000
 02986 49 04046 00000
 02994
 02994 32 06173 00000
 03006 49 04046 00000
 03014
 03014 26 06251 00099
 03026 16 00469 -3061
 03038 16 00445 -0099
 03050 49 00422 -0099
 03062 26 06241 00099
 03074 16 00469 -3109
 03086 26 01260 06251
 03098 49 01262 -6251

FORMAI TF NEWAIJ,AC,, AIJZ
 FA NEWAIJ,AJJZ
 FA NEWAIJ,AII,, A\$AJZ

 EM NEWAIJ,HALFZ

 TF NEWAIJ,AC,, 1/2\$AI6AJZ
 TF NEWAJJ,NEWAIIZ
 FS NEWAIJ,AIJZ

 FA NEWAJJ,AIJZ

 TDM SW261,9,, SW2 ONZ
 TDM J62Z
 DC 1,0,*Z
 BNF PLUS,TEMP,, IS ALPHA-Z
 MINUS TDM J61,8,11Z
 TDM SW361,1,, SW3 OFFZ
 B STOREZ
 DORG #-3Z
 PLUS TDM J61,8Z
 TDM SW361,9,, SW3 ONZ
 TF TEMP,NEWAIIZ
 TF NEWAIJ,NEWAJJZ
 TF NEWAJJ,TEMP,, SWITCH AI-AJZ
 BNF #632,NEWAIJZ
 CF NEWAIJ,,, INVERT AIJ SIGNZ
 B STOREZ
 DORG #-3Z
 SF NEWAIJZ
 B STOREZ
 DORG #-3Z
 SINCOS TF SC,AC,, GAMMAZ
 FA AC,AC,, 2 GAMMAZ

 TF S2,ACZ
 FM SC,SCZ

03110	26	05945	00099	TF	CCS,AC,, GAMMA**2Z
03122	16	00469	-3157	FA	AC,ONE,, 1&GAMMA**2Z
03134	16	00445	-0099		
03146	49	00422	-6017		
03158	26	06190	00099	TF	TEMP,ACZ
03170	16	00469	-3205	FD	S2,TEMPZ
03182	26	01260	06241		
03194	49	01422	-6190		
03206	26	05935	00099	TF	SIN,AC,, SINEZ
03218	26	06200	06017	TF	TEMP2,ONEZ
03230	16	00469	-3265	FS	TLMPC,COS,, 1-GAMMA**2Z
03242	16	00445	-6200		
03254	49	00402	-5945		
03266	16	00469	-3301	FD	TEMP2,TEMPZ
03278	26	01260	06200		
03290	49	01422	-6190		
03302	26	05945	00099	TF	CUS,ACZ
03314	16	00469	-3349	FM	CUC,COSZ
03326	26	01260	05945		
03338	49	01262	-5945		
03350	26	06261	00099	TF	C2,AC,, C**2Z
03362	26	06241	06017	TF	S2,ONE,, S2&C2#1Z
03374	16	00469	-3409	FS	S2,C2,, #SIN**2Z
03386	16	00445	-6241		
03398	49	00402	-6261		
03410	16	00469	-3445	FM	SIN,COSZ
03422	26	01260	05935		
03434	49	01262	-5945		
03446	26	06251	00099	AAA	TF SC,ACZ
03458	16	00469	-3493	FM	SC,AIJ1AJ,, SC&AIJ1-AJJ0Z
03470	26	01260	06251		
03482	49	01262	-6137		
03494	26	06190	00099	TF	TEMP,ACZ
03506	26	00099	06261	TF	AC,C2Z
03518	16	00469	-3553	FS	AC,S2Z
03530	16	00445	-0099		
03542	49	00402	-6241		
03554	16	00469	-3589	FM	AC,AIJZ
03566	26	01260	00099		
03578	49	01262	-6127		
03590	16	00469	-3625	FS	AC,TEMPZ
03602	16	00445	-0099		
03614	49	00402	-6190		
03626	26	06173	00099	TF	NEWAIJ,ACZ
03638	16	00469	-3673	FM	SC,AIJZ

03650	26	01260	06251		
03662	49	01262	-6127	FA	AC,ACZ
03674	16	00469	-3709		
03686	16	00445	-0099	TF	TEMP2,AC,, 2*AIJ*SCZ
03698	49	00422	-0099	FM	C2,AIJZ
03710	26	06200	00099		
03722	16	00469	-3757		
03734	26	01260	06261		
03746	49	01262	-6107		
03758	26	06153	00099	TF	NEWAIJ,ACZ
03770	16	00469	-3805	FM	S2,AJJZ
03782	26	01260	06241		
03794	49	01262	-6117	FA	NEWAIJ,ACZ
03806	16	00469	-3841		
03818	16	00445	-6153	FA	NEWAIJ,TEMPZ
03830	49	00422	-0099		
03842	16	00469	-3877	FM	S2,AIJZ
03854	16	00445	-6153		
03866	49	00422	-6200		
03878	16	00469	-3913		
03890	26	01260	06241		
03902	49	01262	-6107		
03914	26	06163	00099	TF	NEWAIJ,ACZ
03926	16	00469	-3961	FM	C2,AJJZ
03938	26	01260	06261		
03950	49	01262	-6117	FA	NEWAIJ,ACZ
03962	16	00469	-3997		
03974	16	00445	-6163	FA	NEWAIJ,TEMPZ
03986	49	00422	-0099		
03998	16	00469	-4033	FS	NEWAIJ,TEMPZ
04010	16	00445	-6163		
04022	49	00402	-6200		
04034	15	04531	00001		
04046	26	0235P	06163	STORE	TDM SW2&1,1,, SW2 OFFZ
04058	26	0239L	06173	TF	JADD&11,NEWAIJ,6,, IDA* STORE AJJZ
04070	26	0232J	06153	TF	AIJADD&11,NEWAIJ,6,, IDA* STORE AI
04082	26	02282	07227	TF	IADD&11,NEWAIJ,6,, IDA* STORE AIIZ
04094	11	06142	-0001	ROTATE	K,N,, K#N
04106	24	02282	05923	AI	IKUDA-1,1,, STEP COUNTZ
04118	47	04174	01300	C	K#I2
04130	46	04806	01209	BL	SWCHIK,,, K LESS THAN IZ
04142	26	02284	02282	BE	SKIP,,, K#I2
04154	26	02246	05923	TF	K#K,, K GREATER THAN IZ
04166	49	04198	00000	E	I,IIZ
04174				AAIKZ	
				DORG	**-32

04174 26 02284 00923 SWCHIK TF K1,I,, K LESS THAN JZ
 04186 26 02246 02267 TF I1,KZ
 04198 26 06190 02264 AAIK TF TEMP,K1Z
 04210 12 06190 000-3 SM TEMP,3,10Z
 04222 23 06190 02284 M TEMP,K1,, K&K-30Z
 04234 26 06190 00099 TF TEMP,ACZ
 04246 13 06190 000-5 MM TEMP,5,10, 6 DIGITSZ
 04258 11 00099 -7758 AM AC,07758Z
 04270 21 00098 02246 A AC-1,11,, A&AIKZ
 04282 32 00095 00000 SF AC-4Z
 04294 26 04317 00099 TF AIKADD611,ACZ
 04306 26 06153 00000 AIKADD TF AIK,0Z
 04318 24 02262 05925 C K,JZ
 04330 47 04386 01300 BL SWCHJKZ
 04342 46 04806 01200 BE SKIPZ
 04354 26 02248 05925 TF J1,J,, K GREATER THAN JZ
 04366 26 02264 02282 TF K1,KZ
 04378 49 04410 00000 B AAJKZ
 04386 DORG *-3Z
 04386 26 02248 02282 SWCHJK TF J1,K,, K LESS THAN JZ
 04398 26 02284 05925 TF K1,JZ
 04410 26 06190 02284 AAJK TF TEMP,K1,, AJK ADDZ
 04422 12 06190 000-3 SM TEMP,3,10Z
 04434 23 06190 02284 M TEMP,K1Z
 04446 26 06190 00099 TF TEMP,ACZ
 04458 13 06190 000-5 MM TEMP,5,10, 6 DIGITSZ
 04470 11 00099 -7758 AM AC,07758Z
 04482 21 00098 02246 A AC-1,J1Z
 04494 32 00095 00000 SF AC-4Z
 04506 26 04529 00099 TF AIKADD611,ACZ
 04518 26 06163 00000 AJKADD TF AIK,0Z
 04530 49 05116 00000 SW2 B DEG45Z
 04542 16 00469 -4577 FM COS,AIKZ
 04554 26 01260 05945
 04566 49 01262 -6153
 04578 26 06200 00099 TF TEMP2,ACZ
 04590 16 00469 -4625 FM SIN,AJKZ
 04602 26 01260 05935
 04614 49 01262 -6163
 04626 16 00469 -4661 FA TEMP2,ACZ
 04638 16 00445 -6200
 04650 49 00422 -0099
 04662 16 00469 -4697
 04674 26 01260 05935
 04686 49 01262 -6153

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04698 26 06190 00099 TF TEMP,AC,, AIK*SINZ
 04710 16 00469 -4745 FM COS,AJKZ
 04722 26 01260 05945
 04734 49 01262 -6163
 04746 16 00469 -4781
 04758 16 00445 -0099
 04770 49 00402 -6190
 04782 26 0452R 00099 RTSTOR TF AJKADD611,AC,6, IDA* AJK STOREDZ
 04794 26 0431P 06200 TF AIKADD611,TEMP2,6, IDA* AIK STOREDZ
 04806 12 02282 000-1 SKIP SM K,1,10, K-1Z
 04818 47 04106 01200 BNZ ROTATE624,,, RETURNZ
 04830 47 04854 00200 WANTU BNC2 STEP1,,, SKIP PUNCHZ
 04842 38 05922 00400 WNCD I-1,,, PUNCH 1,J,SIN,COSZ
 04854 11 05923 000-1 STEPI AM I,1,10, I6IZ
 04866 24 05923 05925 C I,JZ
 04878 47 05310 01200 BNE RESET2Z
 04890 24 05925 07227 C J,N,, J VS NZ
 04902 47 05286 01300 DL RESET2-24Z
 04914 49 02202 00000 Sw1 B START,,, SOMETIMES NOPZ
 84938 24 87350 87200 BNH E-1,DEFLTA-1,, E VS DELTAZ
 04950 12 07239 000-1 SM E-8,1,10, E/E/10Z
 04962 34 00000 0-102 RCTY Z
 04974 39 06359 00100 WATY EQUALZ
 04986 38 07238 0-100 WNTY E-9Z
 04998 46 05330 01200 BZ TYPOUTZ
 05010 49 02202 00000 B STARTZ
 05018 16 00469 -5053 DORG *-3Z
 05030 26 01260 06429 DEG45 FM SQRT2,AIKZ
 05042 49 01262 -6153
 05054 26 06190 00099 TF TEMP,ACZ
 05066 16 00469 -5101 FM SQRT2,AJKZ
 05078 26 01260 06429
 05090 49 01262 -6163
 05102 26 06200 06190
 05114 16 00469 -5149 FA TEMP2,AC,, AIKZ
 05126 16 00445 -6200
 05138 49 00422 -0099
 05150 16 00469 -5185
 05162 16 00445 -0099
 05174 49 00402 -6190
 05186 49 04762 00000 FS AC,TEMP,, AIKZ
 05198 26 06190 06200 SW3 D RTSTOR,,, NOPZ
 05210 26 06200 00099 TF TEMP,TEMP2,,SWITCH AIK-AJKZ
 TF TEMP2,ACZ

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05222 26 00099 06190
 05234 44 05266 06200
 05246 33 06200 00000
 05258 49 04782 00000
 05266
 05266 32 06200 00000
 05278 49 04782 00000
 05286
 05286 16 05923 000-1
 05298 11 05925 000-1
 05310 11 02255 00C-1
 05322 49 02250 00000
 05330
 05330 34 00000 00102
 05342 34 00000 00102
 05354 16 05923 000-1
 05366 16 05437 -7258
 05378 25 06377 05922
 05390 25 06379 05923
 05402 34 00000 00102
 05414 39 06369 00100
 05426 26 05945 07258
 05438 33 05936 00000
 05450 38 05936 00100
 05462 11 05923 000-1
 05474 11 05436 000-1
 05486 24 05923 07227
 05498 47 05378 01100
 05510 34 00000 00102
 05522 34 00000 00102
 05534 38 06138 00100
 05546 39 06395 00100
 05558 26 06190 07227
 05570 12 06190 000-3
 05582 23 06190 07227
 05594 26 06190 00099
 05606 13 06190 000-5
 05618 11 00099 -7748
 05630 21 00098 07227
 05642 32 00095 00000
 05654 26 05761 00099
 05666 26 05945 06037
 05678 16 05701 -7758
 05690 26 06190 00000
 05702 24 05944 06189

TF AC,TEMPZ
 BNF SETF,TEMP2Z
 CF TEMP2Z
 B RTST0RZ
 DORG *-3Z
 SETF SF TEMPZ,,,INVERT AIK SIGNZ
 B RTST0RZ
 DORG *-3Z
 TFM I,1,10, 1#1Z
 AM J,1,10, J61Z
 RESET2 AM CMPARE5,1,10, A1J61Z
 b CMPARE,,, LOOP BACKZ
 DORG *-3Z
 TYPOUT RCTY Z
 RCTY Z
 TFM I,1,10, 1#1Z
 TFM VAR&11,DIAGZ
 AGAIN TD OUTPUT68,I-1,, SET INDEXZ
 TD OUTPUT610,1Z
 RCTY Z
 WATY OUTPUTZ
 VAR TF COS,DIAGZ
 CF COS-9Z
 WNTY COS-9Z
 AM I,1,10, 161Z
 AM VAR&10,I,10, STEP FETCHZ
 C I,N,, I VS NZ
 BNH AGAINZ
 RCTY Z
 RCTY Z
 WNTY IKUDA-5,,, TYPE ROTATIONSZ
 WATY CNTZ
 TF TEMP,NZ
 SM TEMP,3,10Z
 M TEMP,N,, NN=3#Z
 TF TEMP,ACZ
 MM TEMP,5,10Z
 AM AC,07748Z
 A AC-1,NZ
 SF AC-4Z
 TF ENDSQR&11,ACZ
 TF COS,ZEROZ
 TFM CHANGE&11,07758Z
 CHANGE TF TEMP,00000Z
 C COS-1,TEMP-1Z

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05714 46 05738 01100
 05726 26 05945 06190
 05738 11 05700 000-1
 05750 14 05701 -0000
 05762 47 05690 01100
 05774 34 00000 00102
 05786 39 06039 00100
 05798 38 05936 00100
 05810 15 05922 00000
 05821 1
 05822 38 05922 00400
 05834 34 00000 00102
 05846 34 00000 00102
 05858 46 05890 00200
 05870 39 06203 00100
 05882 49 05902 00000
 05890
 05890 39 06263 00100
 05902 36 00000 00500
 05914 49 00000 00000
 05922

BH *624Z
 TF COS,TEMPZ
 AM CHANGE610,1,10Z
 ENDSQR CM CHANGE&11,0Z
 BNH CHANGEZ
 RCTY Z
 WATY MESS2Z
 WNTY COS-9Z
 TDM I-1Z
 DC 1,@,*Z
 WNCD I-1Z
 PHASE2 RCTY Z
 RCTY Z
 BC2 CALL3Z
 WATY ENDZ
 B CALL3&12Z
 DORG *-3Z
 CALL3 WATY PHASE3,,, INSTRUCTIONSZ
 RNCD 0,,, LOAD PHASE 3 LOADERZ
 B 00,,, EXECUTE LOADERZ
 DORG *-3Z

* PHASE 2 CONSTANTSZ
 ELEMNT DSB 1225,10,7758Z
 DIAG DSB 50,10,7258Z
 E DS 10,7247Z
 RM2 DC 1,@,7248Z
 DELTA DS 10,7237Z
 N DS 27227Z
 I DS 2Z
 J DS 2Z
 SIN DS 10Z
 COS DS 10Z
 RM DC 1@Z
 CMPATB DAC 30,LOAD PHASE 2 OUTPUT-HIT START0Z
 I1 DS 211J168Z
 J1 DS 211J1610Z
 K1 DS 2HIT610Z
 K DS 2HIT68Z
 ONE DC 10,51100000000Z
 HALF DC 10,50500000000Z
 ZERO DC 10,0Z
 MESS2 DAC 30,MAXIMUM AIJ,&I NLT R JD, # @Z
 AII DS 10Z
 AJJ DS 10Z
 AIJ DS 10Z

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U6137	10	AIMIAJ DS	10Z
U6143	6	IKUDA DC	6,0@Z
U6153	10	NEWAI1 DC	10,0Z
U6163	10	NEWAJJ DC	10,0Z
U6173	10	NEWAIJ DC	10,0Z
U6180	7	TAN225 DC	7,5041421Z
U6190	10	TEMP DS	10Z
U6200	10	TEMP2 DS	10Z
UUU99		AC DS	,99Z
06203	15	END DAC	15,END OF PROGRAM@Z
06241	10	S2' DS	10Z
06251	10	SC DS	10Z
06261	10	C2 DS	10Z
06153	10	AIK DS	10,NEWAIIZ
06163	10	AJK DS	10,NEWAJZ
U6263	48	PHASE3 DAC	48,EIGENVALUES DONE. WHEN PHASE 3 LOADS, HIT START@Z
U6359	5	EQUAL DAC	5,E # @Z
U6369	13	OUTPUT DAC	13, A%00# # @Z
U6395	13	CNT DAC	13, ROTATIONS. @Z
06429	10	SQRT2 DC	10,5070710678Z
02178		DEND ENTRYZ	

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PHASE 3

1620 CARD SYSTEMS WITH DIVIDE AND INDIRECT ADDRESSING

SPS LISTING

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* P HASE 3 - EIGENVECTOR COMPUTE 1620 W/DIVIDE & IND. ADD. Z

02178 15 U2419 00-01
 02190 16 U2427 000-1
 02212 34 U0000 00102
 02214 34 U0000 00102
 02226 39 U3835 00100
 02238 34 U0000 00102
 02250 34 U0000 00102
 02262 48 U2273 U2273
 02274 16 U2429 000-1
 02286 16 U2304 -4008
 02298 26 U4008 03933
 02310 11 U2303 000-1
 02322 14 U2301 000K0
 02334 47 U2298 01200
 02346 16 U2364 -4008
 02358 26 U4008 U3923
 02370 11 U2363 000L3
 02382 14 U2364 U4238
 02394 47 U2358 01100
 02406 36 U3804 U0500
 02418 49 U2626 00000
 02430 16 U2993 000-1
 02442 14 U3805 000L2
 02454 46 U2546 01100
 02466 26 U3165 03805
 02478 16 U2865 -3678
 02490 13 U3805 000L3
 02502 21 U2864 00099
 02514 15 U3003 00001
 02526 26 U2889 03805
 02538 49 U2722 00000
 02546
 02546 16 U3165 000L2
 02558 16 U2865 -3998
 02570 13 U3805 000L2
 02582 21 U2864 00099
 02594 16 U2889 000L2
 02616 15 U3U03 00009
 02618 49 U2722 00000
 02626
 02626 26 U3165 03805
 02638 12 U3165 000L2

ENTRY TDM SW161,1,9, 1 OFFZ
 TFM OUTI,1,10, I#1Z
 RCTY Z
 RCTY Z
 WATY MESSGEZ
 RCTY Z
 RCTY Z
 HALT H TEMP,TEMPZ
 TFM OUTJ,1,10Z
 CLEAR TFM SLTI66,MATRIXZ
 SETI TF MATRIX,ZEROZ
 AM *-7,,1,10, DATA AREAW0Z
 CM SETI63,20,10Z
 BNE SETIZ
 ALISET TFM ALLI66,MATRIX,, 18-32Z
 ALLI TF MATRIX,ONE,, 18-32Z
 AM *-7,33,10, 18-32Z
 ALLIZ CM ALLI66,14238,, 18-32Z
 BNH ALLIZ
 READN RNCD N-1Z
 SW1 B PASS2FZ
 TFM ISET611,1,10, SET 1Z
 CM N,32,10Z
 BH OVER32Z
 UNDR33 TF FUNCTN,NZ
 TFM LSTRCD,MATRIX-330Z
 MM N,33,10Z
 A LSTRCD-1,ACZ
 TDM SW261,1,, 2 OFFZ
 TF ICMPAR&11,NZ
 B READZ
 DORG **-3Z
 OVER32 TFM FUNCTN,32,10Z
 TFM LSTRCD,MATRIX-10Z
 MM N,32,10Z
 A LSTRCD-1,ACZ
 TFM ICMPAR&11,32,10Z
 TDM SW261,9,, 2 ONZ
 B READZ
 DORG **-3Z
 PASS2F TF FUNCTN,NZ
 SM FUNCTN,32,10Z

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02650 16 U2665 -3358
 02662 13 U3805 000L3
 02674 21 U2864 00099
 02686 15 U3003 00001
 02698 26 U2889 03805
 02710 16 U2993 000L3
 02722 36 U3808 00500
 02734 45 U3106 03808
 02746 16 U2841 -4008
 02758 25 U3941 02426
 02770 25 U3943 02427
 02782 25 U3947 02428
 02794 25 U3949 02429
 02806 34 U0000 001C2
 02818 39 U3935 00100
 02830 26 U3831 U4008
 02842 38 U3822 001Q0
 02854 14 U2841 -0000
 02866 46 U3002 01200
 02878 14 U2427 -0000
 02890 46 U2934 01300
 02902 11 U2427 000-1
 02914 11 U2840 000-1
 02926 49 U2758 00000
 U2934
 02934 11 U2429 000-1
 02946 16 U2841 -3688
 02958 13 U2429 000L2
 02970 21 U2840 00099
 02982 16 U2427 -0000
 02994 49 U2758 00000
 U3002
 03002 49 U3935 00000
 03014 34 U0000 00102
 03026 39 U3965 00100
 03038 48 U3U49 03049
 03050 15 U2419 00009
 03062 16 U2427 000L3
 03074 16 U2357 U4248
 03086 16 U2393 J9858
 U3098 49 U2202 U0000
 C3106
 03106 16 U3213 -3688
 03118 13 U3809 000L2
 03130 21 U3212 00099

TFM LSTRCD,MATRIX-650Z
 MM N,33,10Z
 A LSTRCD-1,ACZ
 TDM SW261,1,, 2 OFFZ
 TF ICMPAR&11,NZ
 TFM ISET611,33,10, SET 33Z
 READ RNCD I-1,,, READ I,J,S,CZ
 BNR COMPUT,I-1Z
 TYPEV TFM OUTG11,MATRIXZ
 TD TYPE66,OUTI-1Z
 TD TYPE66,OUTIZ
 TD TYPE612,OUTJ-1Z
 TD TYPE614,OUTJZ
 RCTY Z
 WATY TYPEZ
 OUT TF COS,MATRIX,, TYPE VIJZ
 WNTY COS-9Z
 TEST CM OUTG11,,, LAST RECORDZ
 BE SW2Z
 ICMPAR CM OUTI,,, N OR 32Z
 BNL JSETZ
 AM OUTI,1,10, 161Z
 AM OUTG10,1,10Z
 B TYPEVG12Z
 DORG **-3Z
 JSET AM OUTJ,1,10, J&1Z
 TFM OUTG11,MATRIX-320Z
 MM OUTJ,32,10Z
 A OUTG10,ACZ
 ISET TFM OUTI,,, 1 OR 33Z
 B TYPEVG12Z
 BNU ~-Z
 SW2 B PASS2Z
 RCTY Z
 WATY PALMSGZ
 TRICK H TRICKZ,TRICKZ,, ENDZ
 PASS2 TDM SW161,9,, 1 ONZ
 TFM OUTI,33,10, I#33Z
 TFM ALISET&11,MATRIX610240Z
 TFM ALLI2611,19858Z
 B ENTRY624Z
 DORG **-3Z
 COMPUT TFM VKIADD611,MATRIX-320Z
 MM 1,32,10,A&1J#320%I-1&MATRIXZ
 A VKIADD&10,ACZ

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03142	26	03/73	03213		TF	END611,VKIADD611Z
03154	11	03772	-3165		AM	END610,FUNCTNZ
03166	16	03225	-3688		TFM	VKJADD611,MATRIX=3202
03178	13	03811	000L2		MM	J,32,10,A,B1J#320#J-1#GMATRIXZ
03190	21	03224	00099		A	VKJADD610,ACZ
03202	26	03903	00000	VKIADD	TF	VKI,,, STORE VKIZ
03214	26	03913	00000	VKJADD	TF	VKJ,,, STORE VKJZ
03226	45	03474	03813		BNK	HRDWAY,J62,, THETA NOT 45 DEGZ
03238	25	03049	03812		TD	TRICK2,J61,, B OR FLAG 8Z
03250	26	02273	03903		TF	TEMP,VKIZ
03262	16	00469	-3297		FA	TEMP,VKJ,, VKIGVKJZ
03274	16	00445	-2273			
03286	49	0422	-3913			
03298	16	00469	-3333			
03310	26	01260	02273			
03322	49	01262	-3803			
03334	26	02273	00099			
03346	16	00469	-3381			
03358	16	00445	-3913			
03370	49	0402	-3903			
03382	16	00469	-3417			
03394	26	01260	03913			
03406	49	01262	-3049			
03418	44	03714	03812			
03430	26	03903	00099	NEGTV	TF	STORE,J61Z
03442	26	00099	02273		TF	VKI,ACZ
03454	26	02273	03903		TF	AC,TEMPZ
03466	49	03714	00000		TF	TEMP,VKIZ
03474					B	STOREZ
03474	16	00469	-3509		DORG	*-3Z
03486	26	01260	03903	HRDWAY	FM	VKI,COS,, VKI*COSZ
03498	49	01262	-3831			
03510	26	02273	00099			
03522	16	00469	-3557			
03534	26	01260	03913			
03546	49	01262	-3821			
03558	16	00469	-3593			
03570	16	00445	-2273			
03582	49	0422	-0099			
03594	16	00469	-3629			
03606	26	01260	03903			
03618	49	01262	-3821			
03630	26	03903	00099			
03642	16	00469	-3677			
03654	26	01260	03913			

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